The effect of endurance running training on asthmatic adults

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Nine mild to moderate asthmatic adults (three males, six females) and six non-asthmatics (one male, five females) underwent endurance running training three times per week for five weeks, at self selected running speeds on a motorized treadmill. After training, the asthmatic group had a significantly higher maximum oxygen uptake, significantly lower blood lactate and heart rate in submaximal running, and a significantly reduced time to complete a two mile treadmill run, partly attributable to the ability to exercise at a higher %Vo2 max after training. These training induced changes of the asthmatic group were generally of a greater magnitude than those shown by the non-asthmatic group. Although seven of the nine asthmatics did show a reduction in the post-exercise fall in FEV1 after the five week training period, this was not statistically significant for the asthmatic group as a whole. The results of this study therefore suggest that endurance running training can improve the aerobic fitness of asthmatic adults, and may reduce the severity of exercise-induced asthma.

Keywords: Asthma, exercise, running, aerobic capacity, fitness, blood lactate

Introduction

Although physical training is now recommended in the management of asthma to improve cardiorespiratory fitness1, the prescription of the type of exercise is not well defined. Studies on the asthmatic adult have demonstrated improvements in physical fitness after training comprising sports and calisthenics2, circuit training3 and high intensity intermittent exercise4. However, such activities are more likely to lead to gains in strength and muscular coordination than in cardiorespiratory fitness, when compared to continuous aerobic exercise.

Continuous exercise, however, may be a less suitable form of exercise for the asthmatic because it is more likely to provoke exercise induced asthma (EIA) than activity of an intermittent nature5. Furthermore, when compared under conditions of the same relative heat loss, land based activities such as running provoke more EIA than swimming6. Although the safety and beneficial effects of a training programme of endurance running has been reported for asthmatic children7, endurance running has not been evaluated as an activity for previously sedentary asthmatic adults.

The increase in both the rate and depth of ventilation with physical activity is a major cause of EIA in asthmatics8. A number of studies have demonstrated that the severity of EIA at the same work load is reduced after training, which is thought to be due to either a reduction in the ventilatory demands9,10 or the result of a reduction in the basic hyperreactivity of the airways11. In contrast, some studies employing continuous exercise have reported no change in EIA after training12, although the methods of the test for EIA may have been doubtful. In the first study, the work load for the EIA test was not the same before and after training. In the second study, the principle of specificity of training was not recognized because the children were tested for EIA on a cycle ergometer whereas they underwent swimming training. Therefore the effect of a programme of training employing continuous exercise on the severity of EIA merits further attention.

The present study examined the effect of a training programme of endurance running on the cardiorespiratory fitness and the severity of EIA in asthmatic adults.

Methods

Sixteen asthmatic adults (nine males, seven females) from the general public and student populations volunteered for the study. Each had a history of asthma and were on regular medication. Six healthy students, without a previous history of asthma, formed the control group for this study. None of the asthmatic or non-asthmatic subjects were currently engaged in endurance running training, although several of the subjects took part in other forms of activity.

Endurance training was performed three times a week on a motorized treadmill (Woodway Ltd) for five weeks. The speed of the treadmill could be altered using a hand held switch, so that the subjects could train at self-selected speeds. Subjects were encouraged to perform the training sessions at a fairly constant and continuous pace, aiming to improve their endurance as represented by the duration and distance covered in the training session. Throughout each training session, the distance covered, the time...
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elapsed, and the running speed were visible on the screen of a microcomputer. The distance covered and the duration of each training session was recorded in a training diary. The subjects were encouraged not to alter their habitual level of activity, and to perform the running training in addition to other activities in which they normally participated.

The asthmatic subjects were encouraged to take their usual pre-exercise asthmatic medication before each training session (usually an inhaled B2 agonist or disodium cromoglycate), and were asked not to alter their prophylactic asthmatic medication for the duration of the study. The forced expiratory volume in one second (FEV1) was recorded at the start of each training session, both before and after medication, and at between 7 and 10 minutes post-exercise. The percentage fall of the FEV1 after training sessions (from pre-exercise pre-treatment values) was used as a measure of the severity of EIA.

In order to assess the physiological changes associated with the endurance running training, four tests were performed before and immediately after training as described below.

After familiarization with running on the motorized treadmill, the maximum oxygen uptake (VO2 max) was determined during uphill treadmill running using a modification of the protocol of Taylor et al.13. The test, performed by the asthmatics with pre-exercise medication, involved uphill running at a constant speed, with increases in the gradient of 2.5 per cent every three minutes (from an initial slope of 3.5 per cent), until exhaustion. Heart rate was monitored continuously and expired air was collected during the final minute at each gradient and during the final minute of exercise. Expired air samples were analysed for oxygen and carbon dioxide along with the ventilatory volume from which VO2 max was calculated. Subjective ratings of the level of exertion were recorded14; a respiratory exchange ratio (VCO2/VO2) greater than 1.10 was taken as criterion for the achievement of VO2 max.

The second treadmill test involved continuous running on a level treadmill for four minutes at each of four submaximal speeds, selected to elicit approximately 60, 70, 80 and 90 per cent of each individuals VO2 max. Expired air was collected during the final minute at each speed for the determination of oxygen uptake and ventilation. Heart rate was recorded throughout the test. Duplicate capillary blood samples from the thumb were collected at rest and during the final 30 seconds at each running speed, without slowing the treadmill. The blood samples were later analysed for lactic acid using a modification15 of the fluorimetric procedure of Olsen16. The running speed, oxygen uptake and the %VO2 max at a blood lactate concentration of 2 mmol.l-1 was calculated for each subject.

The third test assessed the incidence and severity of exercise-induced asthma (EIA) for the asthmatic subjects only. Asthmatic medication had been withheld for the following periods prior to this test: short acting bronchodilators (i.e. B2 agonists, anti-cholinergics) for eight hours, long acting bronchodilators (i.e. theophylline) and disodium cromoglycate for 24 hours. Inhaled steroids were continued throughout. A continuous protocol was employed with subjects running for two minutes at a warm-up speed, and then six minutes at a faster speed selected to elicit approximately 80 per cent VO2 max for an optimum provocation test17. In order to assess the intensity of the exercise, heart rate was monitored continuously and a sample of expired air was collected during the final minute of exercise for the determination of oxygen uptake. At rest, the forced expiratory volume in one second (FEV1) and the forced vital capacity (FVC) were measured from a dry spirometer (Vitalograph Ltd). These measurements were expressed as a percentage of predicted normal values based on sex and age18. Measurements of FEV1 were made at 1, 5, 10, 15 and 20 minutes after exercise. The maximum percentage fall in the FEV1 after exercise from resting values was calculated for each asthmatic; a reduction greater than 10 per cent confirmed EIA19.

The running speeds for the above three tests were selected according to the running ability of each subject, and remained the same for both the pre- and post-training tests.

The fourth test was a two mile (3.2 km) treadmill time trial in which subjects were encouraged to complete the distance in as fast a time as possible. As for the training sessions, the speed of the treadmill was controlled by each subject using a hand held switch, and details of the running speed, distance covered and time elapsed were visible on the screen of a microcomputer. Expired air collections and heart rate recordings were made every half mile (0.8 km). From the oxygen uptake results the average %VO2 max utilized during the run was calculated.

During each of the tests, heart rate and ECG profiles were monitored continuously using three chest electrodes and an oscilloscope (Rigel Ltd). The collections of expired air were made through a low resistance respirator valve20 via lightweight wide bore tubing into a 150 litre capacity Douglas bag. The samples of expired air were later analysed for the percentages of oxygen and carbon dioxide using a paramagnetic oxygen analyser (Servomex-Taylor Ltd, Model 370A) and an infra-red carbon dioxide analyser (Mines Safety Appliance Ltd., Lira Model 303). The volume of the expired air sample was determined by evacuating the contents of the Douglas bag through a dry gas meter (Parkinson-Cowen Ltd). This allowed the calculation of oxygen uptake (VO2), carbon dioxide production (VCO2) and ventilation rate (V5).

A paired ‘t’ test was used to examine the significance of any changes after training for the asthmatic and non-asthmatic groups, separately. A pooled ‘t’ test was used to compare the pre-training responses of those asthmatics who completed the training with those asthmatics who withdrew from the study, and the quality and quantity of training performed by the asthmatic and non-asthmatic groups. A Pearson product moment correlation was used to examine the interrelationships between the physiological changes induced by training.

Results
Seven of the sixteen asthmatic adults (six males, one female) who started the running training programme withdrew from the study. Although one subject had to discontinue endurance running as a result of an exacerbation of his asthma caused by infection, factors

other than asthma such as lack of time (2), minor injuries (2) and poor motivation to train (2) were the reasons for the non-compliance of these subjects with the training programme. The severity of EIA in the pre-training tests was not significantly different for the seven who withdrew from the study (38.3±17.9 per cent fall FEV1), compared to the nine who completed the study (26.4±11.7 per cent fall FEV1). Similarly the FEV1, expressed as a percentage of predicted normal values, was not significantly different for the group who withdrew from the study (79.5±25.4 per cent) compared to the group who completed the training (88.4±15.1 per cent). All six of the control group completed the study.

The following results are those from the nine asthmatics (three male, six female) and six non-asthmatics (one male, five females) who complied with the training programme, running three times per week for the five week study period. The average total distance run by each subject was not significantly different for the asthmatic (57±26 km) and non-asthmatic (62±11 km) groups. Furthermore, the average intensity of the endurance running training, estimated from the pre-training laboratory tests, was similar for the two groups (A: 83.8±10.0 vs NA: 80.4±6.5 %VO2 max, ns).

The asthmatic group were aged 26±8 years (range 18 to 37 years). The non-asthmatics from the university student population were slightly younger (20±1, range 18 to 21 years. Table 1 gives the FEV1 expressed in absolute values and as a percentage of predicted normal, the percentage fall in the FEV1 after the non-mediated running test, and the asthmatic medication of each of the nine asthmatics on entry to the study. Of the nine asthmatics, eight had had asthma since childhood, and six were taking daily prophylactic medication. The FEV1 represented 88.4±15.1 per cent of the predicted normal (range 65.7-109.2 per cent predicted), indicative of mild to moderate airflow obstruction. In response to the test without medication, each of the nine asthmatics demonstrated at least a 10 per cent fall in FEV1, consistent with exercise induced asthma.

Table 2 gives the response of the asthmatic and non-asthmatic groups to the maximum exercise test. After training, both groups showed significant increases in both VO2 max and test duration. The change in VO2 max was approximately seven per cent for both groups, although there was a large range between subjects from 0 per cent to 24 per cent. There was no significant change in either the maximum ventilation nor in the maximum heart rate for either group.

In the submaximal test, blood lactate was significantly reduced over the range of running speeds for the asthmatic group, whereas a reduction in blood lactate was only detectable at the highest running speed for the non-asthmatic group (Figure 1). Indeed, the running velocity at a reference blood lactate concentra-

### Table 1. The duration of asthma, medication, and the FEV1 at rest and in response to the non-medicated exercise test at entry to the study for the nine asthmatics

<table>
<thead>
<tr>
<th>Age</th>
<th>Duration of asthma (yrs)</th>
<th>I</th>
<th>FEV1 % pred</th>
<th>% Fall FEV1 post exercise</th>
<th>Daily medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>18</td>
<td>9</td>
<td>4.28</td>
<td>86.5</td>
<td>18.2</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>9</td>
<td>3.95</td>
<td>107.0</td>
<td>19.0</td>
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<tr>
<td></td>
<td>22</td>
<td>21</td>
<td>3.45</td>
<td>83.3</td>
<td>20.3</td>
</tr>
<tr>
<td>Females</td>
<td>19</td>
<td>1</td>
<td>3.64</td>
<td>109.2</td>
<td>43.7</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>23</td>
<td>3.57</td>
<td>100.0</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>9</td>
<td>2.95</td>
<td>88.5</td>
<td>10.2</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>30</td>
<td>2.38</td>
<td>69.6</td>
<td>19.3</td>
</tr>
<tr>
<td></td>
<td>35</td>
<td>30</td>
<td>2.00</td>
<td>65.7</td>
<td>37.5</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>30</td>
<td>2.92</td>
<td>86.2</td>
<td>39.7</td>
</tr>
<tr>
<td>Mean</td>
<td>26</td>
<td>18</td>
<td>3.24</td>
<td>88.4</td>
<td>26.4</td>
</tr>
<tr>
<td>±SD</td>
<td>8</td>
<td>11</td>
<td>0.74</td>
<td>15.1</td>
<td>11.6</td>
</tr>
</tbody>
</table>

DSCG – disodium cromoglicate, BDP – beclomethasone dipropionate

### Table 2. The physiological responses to the maximum exercise test before and after training for the asthmatic (n = 9) and non-asthmatic (n = 6) groups

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Run time (min)</td>
<td>VO2max (mL.kg.⁻¹.min⁻¹)</td>
<td>VEmax (L.min⁻¹ BTPS)</td>
<td>HRmax (beats.min⁻¹)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Asthmatics</td>
<td>7.93</td>
<td>9.57**</td>
<td>41.0</td>
<td>43.8*</td>
<td>81.5</td>
<td>85.0</td>
</tr>
<tr>
<td>±SD</td>
<td>1.40</td>
<td>1.53</td>
<td>8.2</td>
<td>8.8</td>
<td>19.4</td>
<td>21.0</td>
</tr>
<tr>
<td>Non-asthmatics</td>
<td>8.32</td>
<td>9.42*</td>
<td>43.0</td>
<td>46.0*</td>
<td>93.1</td>
<td>95.7</td>
</tr>
<tr>
<td>±SD</td>
<td>1.72</td>
<td>2.46</td>
<td>8.2</td>
<td>9.1</td>
<td>22.3</td>
<td>26.0</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01: Significant difference before and after training.
The results from the 3.2 km (two mile) treadmill time trial are shown in Table 3. After training, both groups were able to complete the two miles in a significantly (p < 0.01) faster time. Furthermore, both groups were able to utilize a significantly higher percentage of VO2 max during the two mile time trial, after training (p < 0.05).

The test for exercise-induced asthma was performed at the same absolute running speed before and after training. Although the absolute oxygen uptake for the tests was similar (Pre: 38.1±7.7 vs Post: 36.9±7.7 ml.kg⁻¹.min⁻¹, ns), this represented a lower percentage of VO2 max after training (Pre: 23.0±7.6 vs Post: 20.5±10.7, p < 0.05) and the heart rate (Pre: 181±11 vs Post: 164±11 beats.min⁻¹, p < 0.01) required at this work load were significantly reduced after training. Inspite of the reduced relative exercise intensity of the non-medicated running test after training, there was no significant change in the degree of EIA, with 26.4±11.6 per cent fall in the FEV1 pre-training compared to 23.0±17.5 per cent post-training.

The non-asthmatic group showed a rate of approximately 10 beats.min⁻¹ over the range of submaximal running speeds for the asthmatic group (Figure 2). The non-asthmatic group showed a less pronounced reduction in heart rate, only reaching statistical significance at the highest running speed. There was no significant change in the minute ventilation during the submaximal test for either the asthmatic or non-asthmatic groups.

Figure 1. The blood lactate concentration at a range of submaximal running speeds before (●—●) and after (○—○) training, for a) the asthmatic and b) non-asthmatic groups. Values are mean ± SD. (*p < 0.05)

Figure 2. The heart rate at a range of submaximal running speeds before (●—●) and after (○—○) training for a) the asthmatic and b) non-asthmatic groups. Values are mean ± SD. (*p < 0.05; **p < 0.01)
However, an examination of the individual data revealed that seven out of nine asthmatics showed a reduction in the degree of EIA after training (Figure 3). The changes in the degree of EIA after training within the group was not correlated with the changes in the ventilation required to complete the non-medicated running test ($r = -0.300$, ns). The large increases in the severity of EIA of the two asthmatics may have been due to either the adverse effects of a period of cold weather, or more probably due to modifications in the asthmatic treatment. One of the asthmatics, under the supervision of her general practitioner, stopped taking beclomethasone dipropionate (BDP) for two weeks in the middle of the training period. Although she restarted the BDP prior to the post-training tests, the interruption in treatment seemed to adversely affect her asthma and therefore may account for the increase in the post-exercise fall in FEV$_1$, from 10.2 per cent pre-training to 25.2 per cent post-training. The other asthmatic subject who had an increase in the severity of EIA from 39.7 to 63.6 per cent fall in the severity of EIA from 39.7 to 63.6 per cent fall in FEV$_1$ (4) voluntarily reduced the daily and pre-exercise use of disodium cromoglycate, preferring to use salbutamol as this gave more immediate relief. The alteration in the treatment of these two asthmatics may explain their greater severity of EIA in the post-training tests. The severity of EIA of the seven asthmatics who had no change in treatment was significantly lower after training (Pre: 26.9±10.4 vs Post: 16.9±9.4 per cent fall FEV$_1$, p < 0.01).

There was no difference after training in the baseline lung function measured by the FEV$_1$, FVC and PEFR for the asthmatic group before the test without asthmatic medication and for the non-asthmatic group (Table 4). Figure 4 shows a histogram of the percentage change in the FEV$_1$ from baseline (without medication) after the training sessions. On a few occasions, the FEV$_1$ fell significantly below baseline, although these decreases were always reversed using a $B_2$ agonist from an inhaler or from a ‘spacer’ device. Pre-exercise medication abolished EIA for five of the asthmatics during the majority of the training sessions. For two asthmatics pre-exercise medication failed to abolish the EIA, showing average decreases in FEV$_1$ of 18.1 per cent and 18.8 per cent after the training sessions. The two asthmatics who did not take asthmatic medication had average decreases in FEV$_1$ of 9.6 per cent and 14.1 per cent after the training sessions. One of the asthmatics who did not take pre-exercise medication performed half of his training out of doors. The severity of EIA was greater when training outside (20.9±10.2 per cent fall FEV$_1$) than on the treadmill (8.4±4.8 per cent fall FEV$_1$).

**Discussion**

This study has examined the physiological effects of five weeks of endurance running training in groups of asthmatic and non-asthmatic adults. The training was at self selected running speeds on the treadmill, akin to that which would be undertaken at the start of an endurance running programme performed out of doors. Seven of the sixteen asthmatics who started the training programme withdrew from the study. In only one of these was the reason for withdrawal connected...
to asthma, with an infective exacerbation, and not necessarily due to the training. A similar reduction in numbers has been observed by Bundgaard et al.\textsuperscript{21} when training asthmatic adults.

The five week period of endurance running training resulted in a similar improvement in VO\textsubscript{2} max of approximately seven per cent in both the asthmatic and non-asthmatic groups. This agrees with other investigators examining the effect of short term training in previously untrained non-asthmatic subjects\textsuperscript{22}. However, it has been suggested that parameters measured during submaximal exercise may be more valid indicators of training status than VO\textsubscript{2} max, if for no other reason than submaximal exercise does not require the same high levels of motivation needed in maximum tests\textsuperscript{23}.

During submaximal exercise the asthmatic group showed a significant reduction in the blood lactate concentrations after the five weeks of training, whereas the non-asthmatic group showed no change. The 11 per cent increase in the running speed at the reference blood lactate concentration of 2 mmol.l\textsuperscript{-1} compared favourably to the seven per cent increase in VO\textsubscript{2} max for the asthmatic group, supporting the observation in non-asthmatics that changes in blood lactate concentrations are more sensitive indicators of training adaptations than VO\textsubscript{2} max\textsuperscript{23}. The lower blood lactate at the same absolute work load after training is a reflection of an increased contribution of energy from aerobic metabolism as a result of the increased oxidative capacity of the mitochondria\textsuperscript{24}.

Blood lactate concentrations were however not different when the running speeds were expressed at the same relative exercise intensity (%VO\textsubscript{2} max) before and after training. Previous studies on non-asthmatics have suggested that a period of training longer than five weeks is required to reduce blood lactate at the same relative work load\textsuperscript{25,26}.

The significant reduction in heart rate at submaximal running speeds without any change in the maximum heart rate for the asthmatic group are consistent with the findings reported in studies on physical training in non-asthmatics\textsuperscript{27,28}. The reduced heart rate is thought to be due to an increase in the stroke volume and a decrease in peripheral resistance\textsuperscript{24}.

In addition, an improvement in the running performance over two miles (3.2 km) was also demonstrated, with both groups able to run the distance in a significantly faster time. An improvement in running performance was traditionally associated with an increase in VO\textsubscript{2} max. However, both groups were able to sustain a higher %VO\textsubscript{2} max in the two mile time trial after training, supporting the observations by Daniels et al.\textsuperscript{29} that factors not involved in the test of VO\textsubscript{2} max contribute to the improvements in running performance. The absence of a reduction in blood lactate at the same relative work load after training suggests that the subjects may have tolerated a higher level of blood lactate over the two mile performance trial, enabling them to sustain a higher %VO\textsubscript{2} max after training.

The asthmatic group therefore demonstrated similar and even enhanced improvements in the physiological parameters chosen to measure cardio-respiratory fitness after the five week training period than the non-asthmatic group performing similar training. These differences in the physiological benefits obtained after training between the asthmatic and non-asthmatic groups may be due to the greater initial level of fitness of the non-asthmatic group before training. Asthma does not therefore impair the ability to obtain the physiological benefits associated with endurance running training, supporting observations in asthmatic children\textsuperscript{1}. Endurance running is therefore a good activity for the asthmatic when an improvement in the cardio-respiratory fitness is sought.

A reduction in the severity of EIA at the same absolute work load after training has been observed by a number of studies, and is thought to be due to lower
ventilatory demands\(^9,10\) or more controversially to a reduction in the basic hyperreactivity of the airways\(^1\). It has been suggested that a reduction in EIA is the most important effect of an improvement in physical fitness\(^9\). In the present study, although the group results showed no change in the severity of EIA, seven of the nine asthmatics did show a significant reduction in the severity of EIA after training at the same absolute work load. The increase in the severity of EIA for the remaining two asthmatics could possibly be explained by changes in their medication.

The safety of the programme of endurance running training on the asthmatic adult was also evaluated. Endurance running is not considered the most suitable form of exercise for the asthmatic due to its greater ability to provoke EIA compared to intermittent exercise\(^7\) and swimming\(^6\). Indeed, effective training intensities required to improve cardio-respiratory fitness may provoke EIA in the untreated asthmatic. In this study, seven out of the nine asthmatics took pre-exercise medication to minimise EIA, ensuring that full benefit could be gained from the training programme\(^6\). However, for three of the asthmatics the pre-exercise medication was only partially successful at inhibiting EIA during the training sessions, although the bronchospasm was always immediately reversed by the inhalation of salbutamol. Indeed, when using pre-exercise medication, the severity of EIA after running was not significantly different to that experienced after swimming\(^16\), so that running training is probably no worse at provoking EIA than other activities when pre-exercise medication is taken.

One asthmatic who did not take any medication for his asthma performed half of his training out of doors. The outdoor training sessions provoked more severe EIA than similar indoor training. This observation is consistent with the findings of Eggleston\(^31\) and Shapiro \textit{et al.}\(^32\) who demonstrated that free range running provokes more severe EIA than treadmill running. A further study to evaluate the safety of outdoor running training in the asthmatic adult is required. Indeed, when training in cold conditions it may be necessary for the asthmatic to use face masks to warm and humidify the inspired air\(^33\).

The major findings of this study suggest that adults with mild to moderate asthma show similar and even enhanced improvements in their cardio-respiratory fitness after short term endurance running training when compared to non-asthmatics. The severity of EIA at the same work load was not significantly reduced for the group as a whole by this improvement in physical fitness. Nevertheless, seven of the nine asthmatics did demonstrate a reduction in EIA after training.

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